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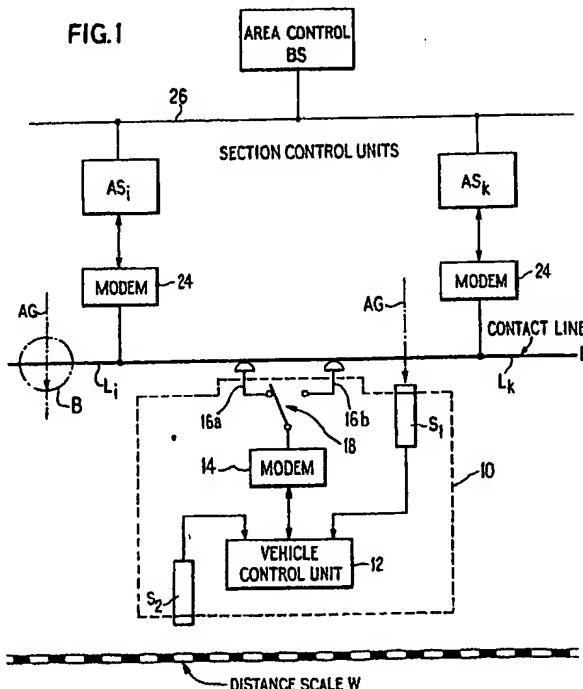
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G4Q

## (54) Preventing collisions between automated vehicles

(57) A method and a vehicle system in which a collision between vehicles travelling one behind the other is avoided. Individual vehicles are interrogated and directed to send out position signals from which the distance between vehicles which directly follow each other in the direction of travel can be determined. From the information received stop or slowing-down signals are derived which prevent a collision between the vehicles.

The system comprises, on each vehicle (10), a vehicle control unit (12) and a transceiver (14) which receives signals from an interrogator in a section control unit (AS<sub>i</sub>) via contact line (L) and contact (16a). The vehicle carries a sensor (S1) which detects passage across boundaries between sections of the contact line and a second sensor (S2) which measures vehicle position along a scale.

FIG.1



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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FIG. 1

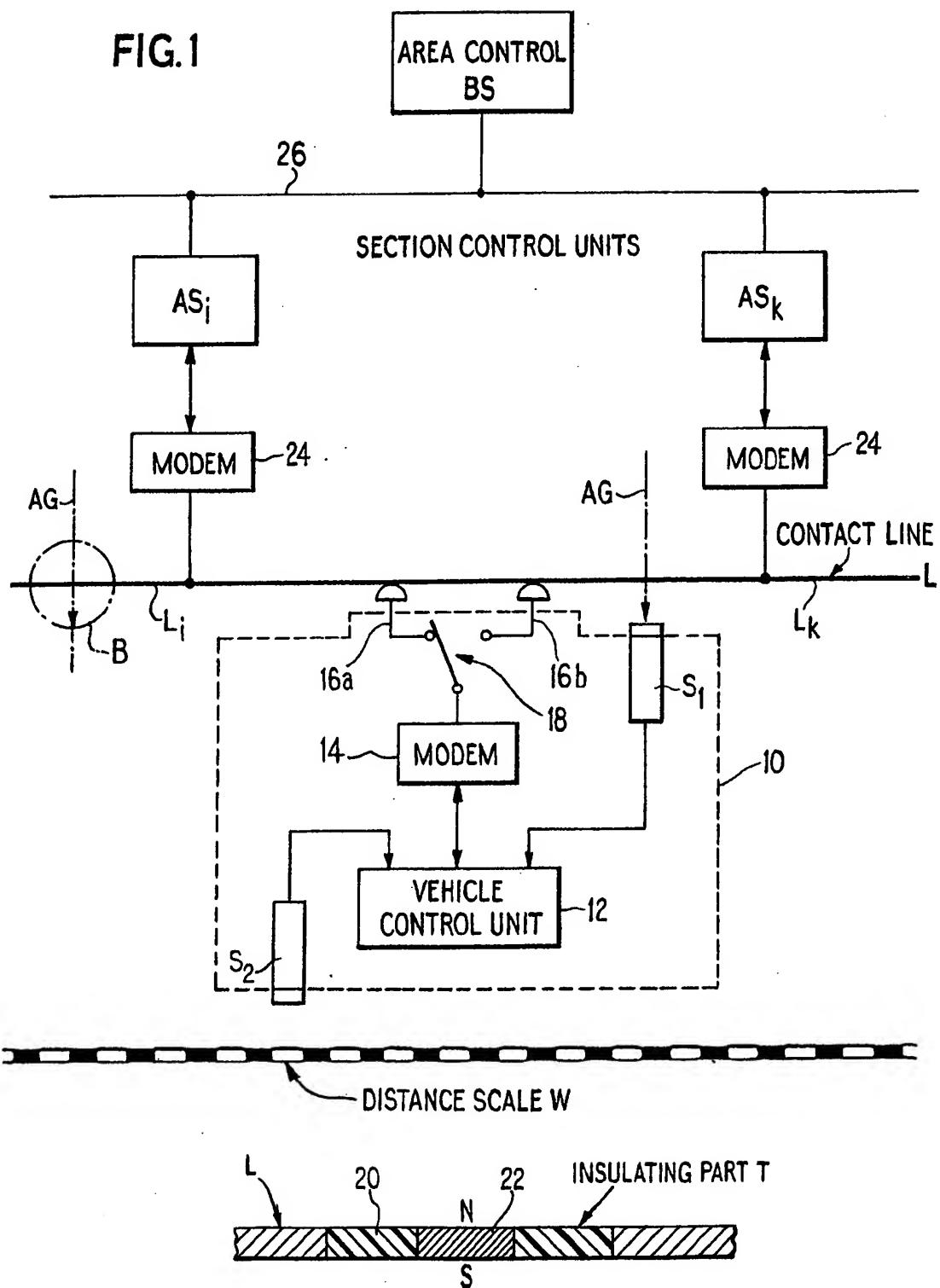


FIG. 2

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## SPECIFICATION

A Method and System for Collision Protection  
between Automated Vehicles

The invention relates a method and a system for collision protection between automated vehicles. The system involves at least one route on which several vehicles can travel, the route being subdivided into several sections and involving control devices for detecting the various vehicle positions and for automatically stopping or slowing down a rear vehicle, following a front vehicle in the direction of travel, when the distance between the two vehicles drops below a predetermined minimum distance.

It is known in automated vehicle systems, to subdivide the travelling route into individual sections, or block sections, and to control the vehicles in such a manner that in each block section of an unbranched travelling route only one vehicle at a time is allowed to move in the direction of travel. It is also known to control the vehicles so that, at least one free block section exists at all times between two vehicles following each other. The vehicle which is the rear vehicle, in the direction of travel, is braked or stopped if this condition is not met. Such a vehicle system is described, for example, in the journal "Maschinenmarkt", Würzburg 88 (1982), 45, pages 915—918.

A disadvantage of the known automated vehicle system is that the control system is relatively rigid in releasing and blocking the individual block sections and does not provide an optimum vehicle speed for all cases. This is because each block section is adjusted for a safety distance which prevents a collision of two vehicles even in the most unfavourable conditions, which rarely exist. The result is that a performance limit of the system is achieved which is below the optimum performance possible.

It is also known in the automated vehicle systems to operate in accordance with the so-called "distance switching method" which basically provides for a higher performance limit and thus is to be preferred in principle. However, the prerequisite for the distance switching method is the existence of devices mounted on board each vehicle which measure the distance to the vehicle travelling in front or else detect when this distance has dropped below an adjustable minimum distance. On the basis of this information control units mounted on board are actuated which can control the vehicle drive. For detecting the distance, proximity switches, particularly contactless switches, can be used at low travelling speeds and with short loads when the minimum distance is comparatively small. At higher travelling speeds and with long loads, which make it necessary to maintain greater minimum distances, ultrasonic, microwave or infra-red sensors can be used which, however, make satisfactory distance measurement possible only on a straight track.

The disadvantage of the distance switching

method described above is that the devices mounted on board the individual vehicles are comparatively elaborate and do not always operate without interference, for example, when interference signals are picked up or the infra-red sensors are dirty.

These disadvantages are avoided in another known distance switching method which operates on the basis of measuring the electrical resistance between at least two sliders of each vehicle which work in conjunction with two contact lines.

In this arrangement only distances of more than two metres can be detected.

An object of the invention is to provide a method and a system for collision protection between automated vehicles, in which it is possible to predetermine optimum minimum distances between the vehicles in accordance with the vehicle speed. It is thus possible to achieve a higher performance from the system.

Thus in accordance with the present invention there is provided a method for collision prevention between automated vehicles involving at least one travelling route on which several vehicles can

travel, the route being subdivided into several sections and involving control devices for detecting the various vehicle positions and for automatically stopping or slowing down a rear vehicle following a front vehicle in the direction of

travel, when the distance between the two vehicles drops below a predetermined minimum distance, in which, in each section and for each vehicle, the distance of the route covered by the vehicle concerned in the appropriate section is

continuously measured, and for each section a clock pulse is generated at predetermined points in time, a position signal is generated as a function of each clock pulse for each vehicle, the position signal being delayed with respect to its related clock pulse by a time interval which is proportional to the distance along the route travelled by the vehicle concerned, and the distances between the vehicles are determined as a function of the points in time when their associated position signals occur.

From another aspect, in accordance with this invention, there is provided an automatic vehicle system comprising at least one travelling route on which several vehicles can travel, the route being

subdivided into several sections, and comprising control devices for detecting the positions of the various vehicles and for automatically stopping or slowing down the rear vehicle, following a front vehicle in the direction of travel, when the

distance between the two vehicles drops below a predetermined minimum distance, in which distance measuring devices are provided by which, in each section and for each vehicle, the distance of the route travelled by the vehicle concerned in the section concerned can be

measured, clock pulse generating devices being provided by which, for each section at predetermined times, a clock pulse can be generated, position signal generating devices

being provided with the aid of which, as a function of each clock pulse for each vehicle, a position signal can be generated which is delayed with respect to its related clock pulse by a time

5 interval proportional to the distance along the route travelled by the vehicle concerned, distance detecting devices being provided by which the distances between the vehicles can be determined as a function of the times of the

10 occurrence of the position signals associated with these vehicles, and each vehicle having allocated to it a transceiver by which the various signals, including the start and stop signals for the vehicle drive, can be transmitted between control devices

15 associated with the vehicle and control units which are stationary.

An important advantage of the invention lies in the fact that the distance information is available with adequate accuracy over the most significant 20 range of distances i.e. from 0.2 to 6 m. Furthermore the maintenance of a speed-related minimum distance is possible even on bends.

It is also of advantage that the amount of data to be transferred for determining the distances 25 between the individual cars is extremely small. Because the position signals, which may consist of a single pulse, are logically combined with the distance along the route travelled in the section concerned, and after a clock pulse is sent out for 30 the section concerned, each vehicle "reports" with its position signal in accordance with the distance travelled by it, the position signals are staggered in time and consequently can be comfortably processed. As a result of the 35 separation in time of the position signals it is also possible to transfer additional data simultaneously with each position signal. Such data may be, for example, the vehicle number of the destination of the trip. The separation in time with which the 40 vehicles communicate with the stationary control devices has an advantage since, corresponding to the minimum distance to be maintained between the vehicles, a corresponding minimum time is also available for data transmission. This enables 45 the electronic components customarily used for the control system to be relatively "slow" whilst being highly efficient.

Preferably the stationary control devices 50 comprise central control devices for the whole vehicle system, an area control unit for each area and section control units allocated to the individual sections, and each section control unit is associated with a transceiver unit by which signals can be transferred from and to the vehicles in the 55 section concerned. With this structuring of the stationary control devices, decentralised data processing can be achieved which offers clear advantages with respect to operating speed and quantity of data at the individual subunits. The 60 loading of the central control devices is simultaneously relieved and also the number of control and data links between the individual assemblies is less than with a central control system without distributed sub-units.

65 Also, preferably, the transceiver units on the

individual vehicles are equipped with sliders making contact with contact lines, associated with the individual sections, for the transmission of data from and to the section control units. This 70 is advantageous because it has been found that the data transmission via contact lines is more reliable, especially when the system is structured into individual sections, than wireless data transmission methods.

75 Preferably the contact line sections are separated from each other by means of insulating parts and each vehicle is fitted with a first sensor which responds when an insulating part is passed. This provides each vehicle immediately with the 80 information on reaching a new section of the route and can be used, for example, for resetting the distance-measuring device associated with the vehicle.

85 Preferably each distance measuring device comprises for each section, a scannable distance scale and a second sensor on each vehicle for scanning this distance scale. With this development of the distance measuring devices the respective distance covered can be measured 90 especially accurately. The second sensors may be like the first sensors, optical sensors, or contactless proximity switches.

The invention is illustrated, merely by way of example, in the accompanying drawings, in 95 which:

Figure 1 is a block diagram of a section of an automated vehicle system in accordance with the invention, and

Figure 2 shows an enlarged section B of a contact line shown in Figure 1.

100 The essential elements of a vehicle are combined in Figure 1 in a block 10 shown in dashed line. The vehicle includes a vehicle control unit 12 and a transceiver unit which, for simplicity, is called a modem 14. In addition, the vehicle includes two sensors S<sub>1</sub> and S<sub>2</sub> and two sliders 16a, 16b. The slider 16a located in front of slider 16b (considered in the direction of travelling) is connected via a change-over switch 110 18 to the modem 14.

The sliders 16a, 16b make contact with a contact line L. At the ends of each section of the contact line L, that is to say at section boundaries AG, the line is interrupted by an insulating part T.

115 The insulating part T (Figure 2) consists of insulating material 20 into which a permanent magnet 22 is embedded directly on the section boundary AG. This permanent magnet 22 can actuate the sensor S<sub>1</sub> when the sensor S<sub>1</sub> passes a section boundary AG if the sensor S<sub>1</sub> is constructed, for example, as a contactless proximity switch. If an inductive proximity switch is used as sensor S<sub>1</sub>, the permanent magnet 22 could be replaced by a simple metal part.

120 125 The second sensor S<sub>2</sub> works in conjunction with a distance scale W. The second sensor S<sub>2</sub> can also be a contactless proximity switch which responds to the presence or absence of metallic material in front of the active area of the proximity switch. The sensor S<sub>2</sub> may alternatively be an

optical sensor which responds to differences in the reflectivity of the individual sections, shown black and white in the drawing, of the distance scale W.

5 Corresponding marks, which can be detected by an optical sensor, could also be provided on the insulating part T so that the first sensor  $S_1$  could also be constructed as an optical sensor. The two sensors  $S_1$  and  $S_2$  are connected to the 10 vehicle control unit 12 which, in turn, is connected to the modem 14.

Figure 1 also shows the stationary control devices which include two section control units  $AS_i$ ,  $AS_k$ . Each unit is connected via a modem 24 to respective contact line sections  $L_i$ ,  $L_k$ . Section control units  $AS_i$ ,  $AS_k$  of each travelling route are each connected via a connecting line 26 to an area control unit BS which, with the other area control units of the system, is connected to a 20 central control unit (not shown).

The vehicle system works as follows. A stationary section control unit  $AS_i$  sends out an interrogation pulse which is converted by the associated modem 24 into a frequency signal, for 25 example one having a frequency of 10 kHz, and is applied to contact line section  $L_i$ .

At the same time as they receive the interrogation pulse (which, because of its periodic transmission, is called a "clock pulse" in the 30 present application) all vehicle control units 12 of the vehicles read off the running distance, determined by their distance measuring devices, in the section concerned. The running distance is stored in the form of a count in a counter which is 35 supplied with the output signals of the second sensor  $S_2$ , which works in conjunction with the distance scale W. The counter is reset to zero when the first sensor  $S_1$  supplies a reset pulse each time it runs over a section boundary AG.

40 Alternatively, particularly with a low pulse repetition frequency of the clock pulses, in each vehicle control unit 12 the distance count may be read off again at a time  $t - t_{clock} = x/a$  and operations are then carried out with the new 45 count. In this formula  $a = \text{Interrogation speed} = \text{length of section}/\text{duration of period of the clock pulse repetition frequency}$ .

Each vehicle control unit 12 then determines from the distance count the interval  $\Delta t = x/a$  and at 50 time  $t_{clock} + \Delta t$  transmits a position signal in the form of a reply pulse. The reply pulse is then converted by the associated modem 14 into a frequency signal, for example one having a frequency of 16 kHz, and is applied via the 55 respective active slider 16a or 16b, to the contact line L.

This position signal is received, at least by the section control unit  $AS_i$  concerned, and from the time of its occurrence the distance  $x = a\Delta t$  travelled 60 by the vehicle or the position of the vehicle 10 in the appropriate section can be calculated. From this information, and from the corresponding data supplied by the other vehicles 10, the distances between the individual vehicles 10 can then be 65 calculated. Then, for example, the position

information of the rearmost vehicle in a section can be compared with the position information of the frontmost vehicle in the section preceding in the direction of travel so that a collision is reliably prevented even when the section boundaries AG are crossed. The trans-boundary information can be processed in various ways in the section control units in the area control unit, and possibly also in the vehicle control units 12. The

70 system ensures that two vehicles travelling one behind the other in different sections do not collide with each other, as well as ensuring that two vehicles travelling one behind the other in the same section do not collide. This is achieved by 80 switching off the vehicle drive of the appropriate rear vehicle when the distance between this vehicle and the vehicle travelling in front drops below a predetermined minimum distance.

A numerical example of the illustrated 85 embodiment will now be discussed. Suppose the section length is 25 m and the operational scanning period is 10 Hz which corresponds to a scanning rate of 250 m/s.

The vehicle control unit 12, in which a distance 90 count, corresponding to a distance of 10 m, is read off for the distance travelled in the section concerned, sends the position signal with a delay of  $\Delta t = 4 \times 10^{-2}$  s with respect to the clock pulse, or frequency signal.

95 A vehicle control unit 12, the count of which corresponds to a distance of 11 m travelled, sends the position signal with a delay of  $\Delta t' = 4.4 \times 10^{-2}$  s with respect to the clock signal, that is to say by  $4 \times 10^{-3}$  s later. From the time 100 intervals between the position signals the vehicle distance 'a' can then be calculated as a function of the known scanning rate in accordance with the following equation:

$$a = a(\Delta t' - \Delta t) = 250 \text{ m/s} \times 4 \times 10^{-3} \text{ s} = 1 \text{ m.}$$

105 This numerical example makes it clear that the vehicle distance can be determined with high resolution even in the millisecond range. This is reliably achieved even with relatively "slow" electric or electronic devices.

110 In a modified embodiment of the invention, the system operates as follows:—

All the vehicle control units 12 of the vehicles 10 in the section concerned start a timer (onboard clock) on receiving a clock or sampling pulse, 115 starting at the count of zero.

The timer operates with a counting frequency 'f' which equals the number of distance count pulses for the maximum section length multiplied by the Interrogation clock frequency. As soon as a 120 vehicle control unit 12 recognises that its time count is greater than or equal to its distance count, it sends its position signal in the form of a reply pulse which is converted by the associated modem 14 into a frequency signal, for example 125 with a frequency of 16 kHz, and is supplied via the respective active slider 16a or 16b to the contact line L.

Simultaneously, the vehicle control unit 12

sets its timer to an initial value which corresponds to the respective minimum distance to the vehicle 10 moving in front of it and starts the timer counting backwards. If the vehicle control unit 12 receives the next position signal—originating from the vehicle 10 moving in front of it—before its counter has reached the count of zero, it switches the vehicle drive to stop or to a lower travelling speed.

10 The section control unit AS<sub>i</sub>, AS<sub>k</sub> also receives the position signals of all vehicles 10 present and can monitor their movement and, if necessary, intervene in the track operations, for example as a result of information supplied by its area control unit ES. In addition, the section control unit AS<sub>i</sub>, AS<sub>k</sub> receives the position information of the rearmost vehicle in the section located ahead, in the direction of travel, and can thus ensure that a collision is prevented.

15 In this embodiment, suppose the maximum section length again be 25 m, the distance counter supplies 100 pulses/m and the scanning clock is 10 Hz. The timer frequency of all on-board clocks is thus 25 kHz.

20 If, in this embodiment, a vehicle control unit 12 recognises, for example,  $4 \times 10^{-2}$  s after the sampling or clock pulse, respectively, 1,000 counted pulses each in coincidence in the counter and in the distance counter, it sends out its position signal.

25 At this time, the vehicle 10 has travelled a distance of 10 m (starting from the beginning of the section). The on-board clock is set to 150—corresponding to a minimum distance of 1.5 m—and is started to count backwards.

30 The control unit 12 of a second vehicle 10 recognises, for example  $4.4 \times 10^{-2}$  s after the sampling clock pulse, that is to say  $4 \times 10^{-2}$  s later, in coincidence 1,100 counted pulses in the distance counter and the on-board clock and sends its position signal. The control unit 12 of the rear vehicle 10 receives the signal, stops its on-board clock—whose count is 50—and stops the vehicle because the distance to the vehicle in front of it is about 1 m.

35 **CLAIMS**

1. A method for collision prevention between automated vehicles involving at least one travelling route on which several vehicles can travel, the route being subdivided into several sections and involving control devices for detecting the various vehicle positions and for automatically stopping or slowing down a rear vehicle following a front vehicle in the direction of travel, when the distance between the two vehicles drops below a predetermined minimum distance, in which, in each section and for each vehicle, the distance of the route covered by the vehicle concerned in the appropriate section is continuously measured, and for each section a clock pulse is generated at predetermined points in time, a position signal is generated as a function of each clock pulse for each vehicle, the position signal being delayed with respect to its

40 related clock pulse by a time interval which is proportional to the distance along the route travelled by the vehicle concerned, and the distances between the vehicles are determined as a function of the points in time when their associated position signals occur.

45 2. An automated vehicle system comprising at least one travelling route on which several vehicles can travel, the route being subdivided into several sections, and comprising control devices for detecting the positions of the various vehicles and for automatically stopping or slowing down the rear vehicle, following a front vehicle in the direction of travel, when the distance between the two vehicles drops below a predetermined minimum distance, in which distance measuring devices are provided by which, in each section and for each vehicle, the distance of the route travelled by the vehicle concerned in the section concerned can be measured, clock pulse generating devices being provided by which, for each section at predetermined times, a clock pulse can be generated, position signal generating devices being provided with the aid of which, as a function of each clock pulse for each vehicle, a position signal can be generated which is delayed with respect to its related clock pulse by a time interval proportional to the distance along the route travelled by the vehicle concerned, distance detecting devices being provided by which the distances between the vehicles can be determined as a function of the times of the occurrence of the position signals associated with these vehicles, and each vehicle having allocated to it a transceiver by which the various signals, including the start and stop signals for the vehicle drive, can be transmitted between control devices associated with the vehicle and control units which are stationary.

50 3. An automated vehicle system according to claim 2 in which the stationary control units comprise central control units, an area control unit for each area and section control units which are associated with individual sections, each section control unit having allocated to it a transceiver by which signals can be transmitted from and to the vehicles in the section concerned.

55 4. An automated vehicle system according to Claim 2 or 3, in which the transceivers belonging to the individual vehicles are equipped with sliders for making contact with contact line sections, associated with the individual sections, for the transmission of data from and to the section control units.

60 5. An automated vehicle system according to Claim 4, in which the contact line sections are separated from each other by insulating parts, and each vehicle is equipped with a first sensor which responds to an insulating part when that part is passed.

65 6. An automated vehicle system according to Claim 5 in which the first sensor is a contactless proximity switch and the insulating part incorporates a magnet adapted to operate said switch.

7. An automated vehicle system according to Claim 5 and in which the first sensor is an inductive proximity switch and the insulating part includes a metal portion adapted to operate the switch.

8. An automated vehicle system according to Claim 5 and in which the first sensor is an optical device and the insulating part has marks on it detectable by the optical device.

10 9. An automated vehicle system according to any of Claims 2 to 8, in which the distance measuring devices for each section comprise a scannable distance scale and a second sensor on each vehicle for scanning this distance scale.

15 10. A method according to claim 1 or a system according to any of claims 2 to 9 in which said rear vehicle is stopped or slowed down by automatically switching off the vehicle drive.

11. A method for collision protection in an automated vehicle system substantially as hereinbefore particularly described and as illustrated in the accompanying drawings.

12. An automated vehicle system substantially as hereinbefore particularly described and as shown in the accompanying drawings.

13. An automated vehicle system according to any of claims 2 to 9 when used in a method according to claim 1.

14. Any novel integer or step, or combination of integers or steps, hereinbefore described, irrespective of whether the present claim is within the scope of, or relates to the same or a different invention from that of, the preceding claims.

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